

**ATTACHMENT E: POST-INJECTION SITE CARE AND SITE CLOSURE PLAN  
40 CFR 146.93(a)**

**CTV III**

**Facility Information**

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Location:



This Post-Injection Site Care and Site Closure (PISC) plan describes the activities that Carbon TerraVault Holdings, LLC (CTV) will perform to meet the requirements of 40 CFR 146.93. CTV will monitor ground water quality and track the position of the carbon dioxide plume and pressure front for 50 years post injection. CTV will not cease post-injection monitoring until a demonstration of non-endangerment of USDWs has been approved by the UIC Program Director pursuant to 40 CFR 146.93(b)(3). Following approval for site closure, CTV will plug all monitoring wells, restore the site to its original condition, and submit a site closure report and associated documentation.

**Pre- and Post-Injection Pressure Differential [40 CFR 146.93(a)(2)(i)]**

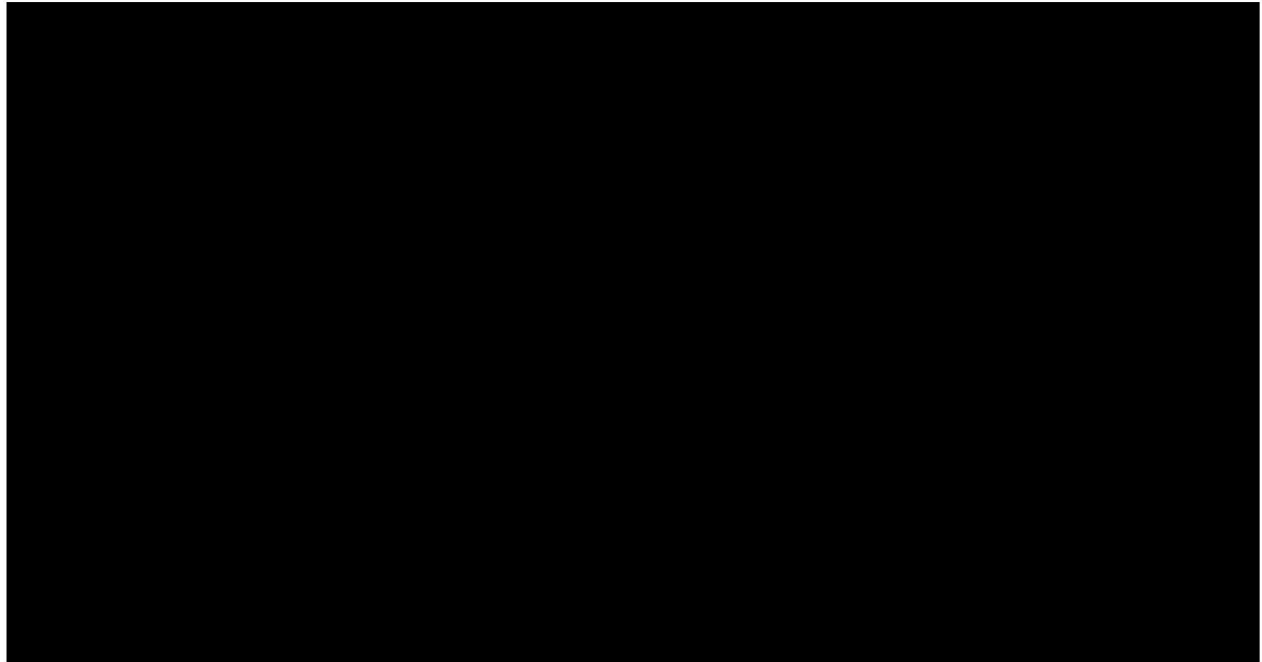
Based on the computational modeling, pressure in the injection area is expected to stabilize approximately 50 years after injection ceases. Injection limits will be based on the fracture pressure of the [REDACTED] Additional information on the projected post-injection pressure declines and differentials is presented in the permit application, and the AoR and Corrective Action Plan.

**Discussion**

The storage reservoir will be operated such that the bottom hole injection pressures will not exceed the fracture pressure of the reservoir with a 10% safety factor.

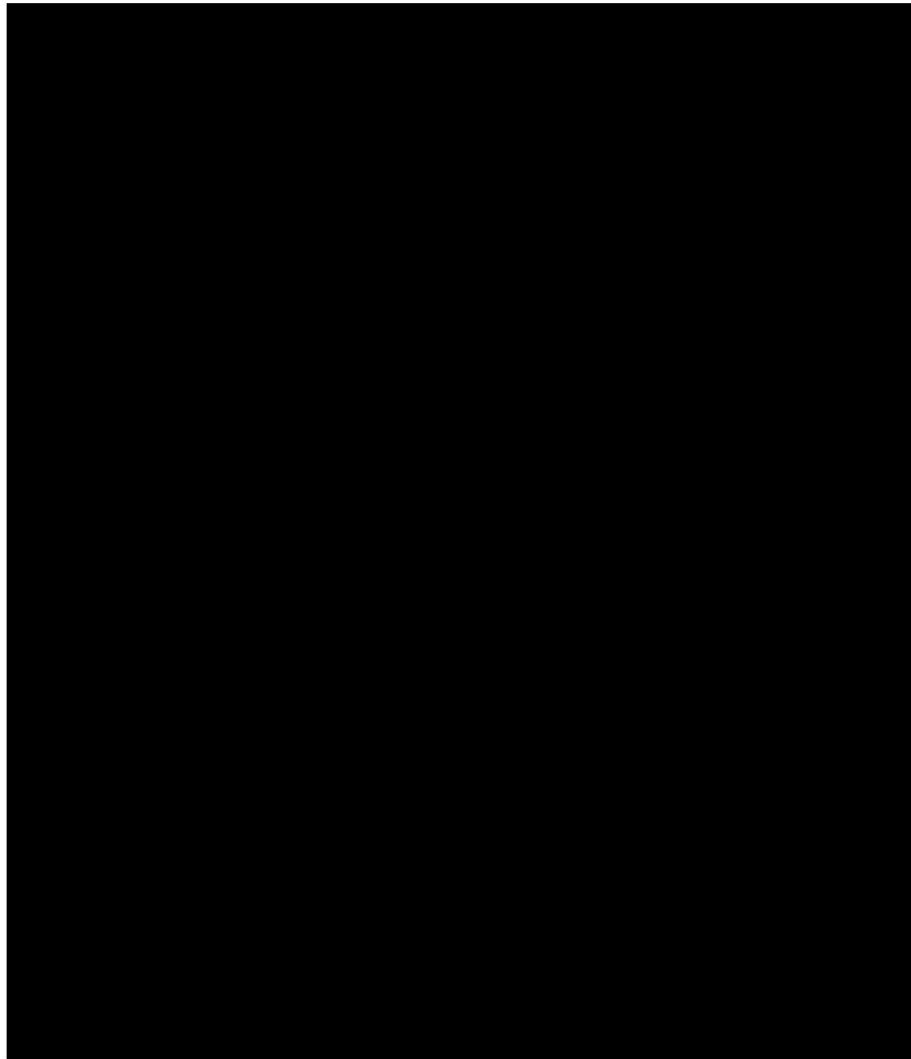
The pressure near the injection site is approximately 2860 psi prior to the start of injection. As shown in Figure 1 the pressure at the injection site peaks 14 years into injection with 3184psi modeled to be seen at the monitoring well location M2. Once injection ceases, the pressure is expected to drop fairly rapidly, with pressure dropping down to 2950 psi at the monitoring well

M2 within 10 years of the end of injection. 50 years after the end of injection the pressure in the reservoir is expected be back approximately to initial conditions.



**Predicted Position of the CO<sub>2</sub> Plume and Associated Pressure Front at Site Closure [40 CFR 146.93(a)(2)(ii)]**

Figure 2 shows the predicted maximum extent of the plume and pressure front during the PISC timeframe. This map is based on the final AoR delineation modeling results submitted pursuant to 40 CFR 146.84. Figures 3 and 4 show the development of the CO<sub>2</sub> plume during the injection period and after the cessation of injection. 52 years after the cessation of injection, the CO<sub>2</sub> plume has largely stabilized, and no further movement is expected.



#### **Post-Injection Monitoring Plan [40 CFR 146.93(b)(1)]**

Monitoring during the post-injection phase will include a combination of groundwater pressure, fluid composition and storage zone pressure as described in the following sections and will meet the requirements of 40 CFR 146.93(b)(1). The results of all post-injection phase testing and monitoring will be submitted annually, within 90 days, as described under “Schedule for Submitting Post-Injection Monitoring Results,” below.

A quality assurance and surveillance plan (QASP) for all testing and monitoring activities during the injection and post injection phases is provided in the Appendix to the Testing and Monitoring Plan.

Post-injection monitoring will include a combination of groundwater monitoring, and storage zone pressure monitoring. Pressure monitoring of the [REDACTED] storage reservoir will monitor for pressure stabilization. This is the best method to confirm confinement of the reservoir. If pressure in the reservoir trends lower post injection and is inconsistent when compared to computational modeling results, CTV will assess for potential leakage.

Throughout the AoR there are USDWs. As such, ongoing groundwater monitoring of the USDWs will assess potential impacts. Groundwater samples will be analyzed annually for indicators of CO<sub>2</sub> movement into the USDWs.

CTV has obtained surface access rights for the duration of the project.

### ***Monitoring Above the Confining Zone***

Table 1 presents the monitoring methods, locations, and frequencies for monitoring above the confining zone. Table 2 identifies the parameters to be monitored and the analytical methods CTV will employ.

**Table 1. Monitoring of ground water quality and geochemical changes above the confining zone.**

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage	Frequency	Depth (feet)
	Fluid sampling	USDW Monitoring Well	AoR	Annually	
	Pressure and Temperature	USDW Monitoring Well	AoR	Continuously	
	Fluid sampling	D1	AoR	Annually	
	Pressure and Temperature Monitoring	D1	AoR	Continuously	

**Table 2. Summary of analytical and field parameters for ground water samples.**

Parameters	Analytical Methods
<b>USDW and</b>	
Cations (Al, Ba, Mn, As, Cd, Cr, Cu, Pb, Se, ZN, TI)	ICP-MS EPA Method 6020
Cations (Ca, Fe, K, Mg, Na, Si)	ICP-OES EPA Method 6010B
Anions (Br, Cl, F, NO <sub>3</sub> , SO <sub>4</sub> )	Ion Chromatography, EPA Method 300.0
Dissolved CO <sub>2</sub>	Coulometric titration ASTM D513-11
δ <sup>13</sup> C	Isotope ratio mass spectrometry
Hydrogen Sulfide	ISBT 14.0 (GC/SCD)

Parameters	Analytical Methods
Oxygen, Argon and Hydrogen	ISBT 4.0 (GC/DID) GC/TCD
Total Dissolved Solids	Gravimetry; Method 2540 C
Alkalinity	Method 2320B
pH (field)	EPA 150.1
Specific Conductance (field)	SM 2510 B
Temperature (field)	Thermocouple

**Table 3. Sampling and recording frequencies for continuous monitoring.**

Parameter	Device(s)	Location	Min. Sampling Frequency	Min. Recording Frequency
During active injection	Pressure Gauge	USDW Monitoring Well	5 hours	5 hours
Post injection	Pressure Gauge	USDW Monitoring Well	12 hours	12 hours

**Notes:**

- Sampling frequency refers to how often the monitoring device obtains data from the well for a particular parameter. For example, a recording device might sample a pressure transducer monitoring injection pressure once every two seconds and save this value in memory.
- Recording frequency refers to how often the sampled information gets recorded to digital format (such as a computer hard drive). For example, the data from the injection pressure transducer might be recorded to a hard drive once every minute.

***Carbon Dioxide Plume and Pressure Front Tracking [40 CFR 146.93(a)(2)(iii)]***

CTV will employ direct and indirect methods to track the extent of the carbon dioxide plume and the presence or absence of elevated pressure.

Table 4 presents the direct and indirect methods that CTV will use to monitor the CO<sub>2</sub> plume, including the activities, locations, and frequencies CTV will employ. The parameters to be analyzed as part of fluid sampling in the [REDACTED] (and associated analytical methods) are presented in Table 5.

Table 6 presents the direct and indirect methods that CTV will use to monitor the pressure front, including the activities, locations, and frequencies CTV will employ.

Fluid sampling will be performed as described in B.1. of the QASP; sample handling and custody will be performed as described in B.3. of the QASP; and quality control will be ensured using the methods described in B.5. of the QASP.

**Table 4. Post-injection phase plume monitoring.**

Target Formation	Monitoring Activity	Monitoring Location(s)	Frequency
<b>DIRECT PLUME MONITORING</b>			
	Fluid Sampling	M1, M2	Annually
<b>INDIRECT PLUME MONITORING</b>			
	Pulse neutron logging	M1, M2	Every five years

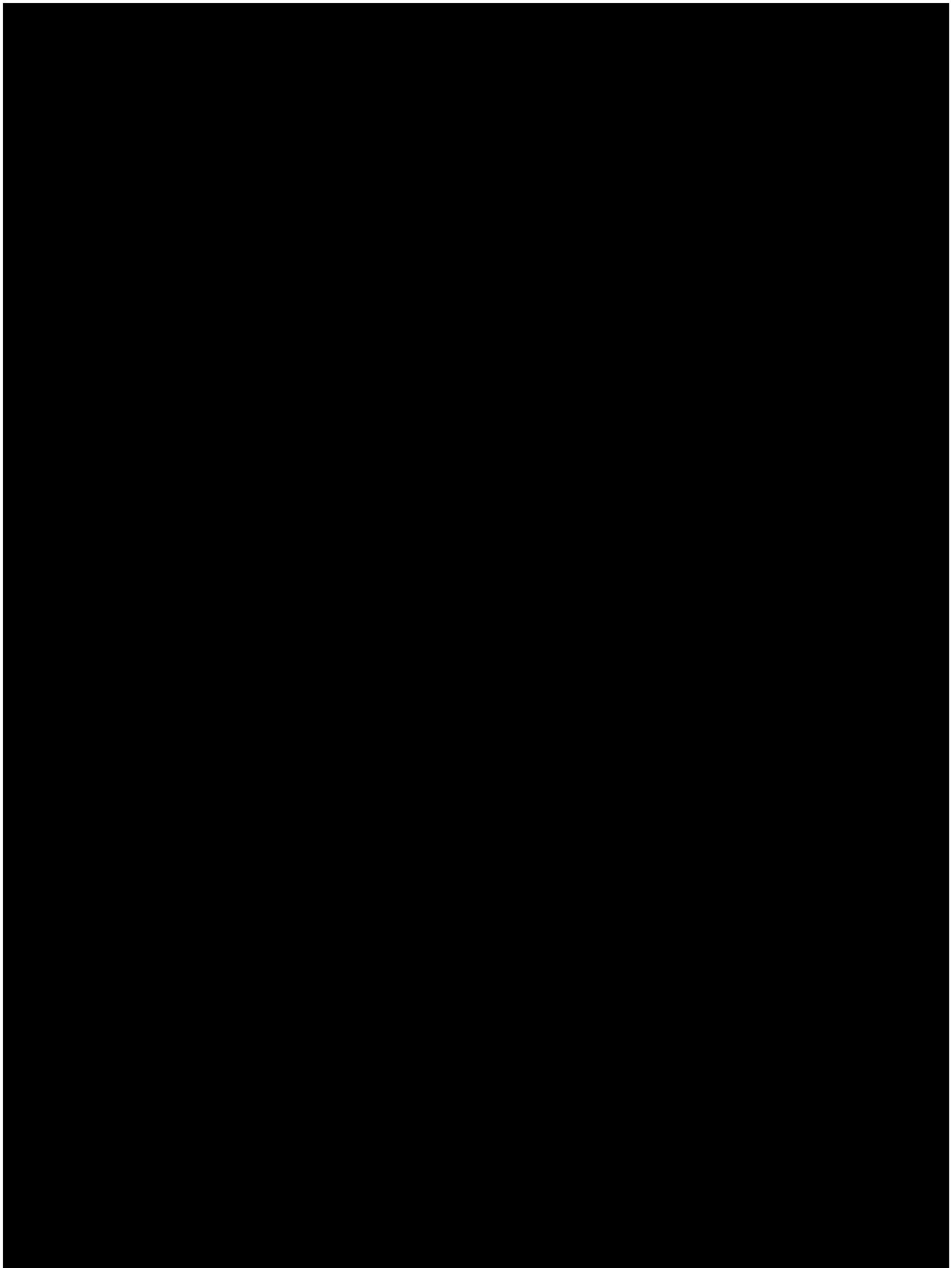
**Table 5. Summary of analytical and field parameters for fluid sampling in the injection zone.**

Parameters	Analytical Methods
Cations (Al, Ba, Mn, As, Cd, Cr, Cu, Pb, Se, ZN, Tl)	ICP-MS EPA Method 6020
Cations (Ca, Fe, K, Mg, Na, Si)	ICP-OES EPA Method 6010B
Anions (Br, Cl, F, NO3, SO4)	Ion Chromatography, EPA Method 300.0
Dissolved CO <sub>2</sub>	Coulometric titration ASTM D513-11
δ13C	Isotope ratio mass spectrometry
Hydrogen Sulfide	ISBT 14.0 (GC/SCD)
Oxygen, Argon and Hydrogen	ISBT 4.0 (GC/DID) GC/TCD
Total Dissolved Solids	Gravimetry; Method 2540 C
Alkalinity	Method 2320B
pH (field)	EPA 150.1
Specific Conductance (field)	SM 2510 B
Temperature (field)	Thermocouple

CTV will employ indirect and direct methods to monitor the pressure front (Table 6). Direct monitoring will include pressure gauges to monitor the pressure of the CO<sub>2</sub> plume in the three monitoring wells. Additionally, seismic monitoring via installed surface and/or shallow borehole seismometers well will be utilized to detect micro seismic events. Figures 3 and 4 show the location of the monitoring wells and the predicted extent of the CO<sub>2</sub> plume in plan view and cross-section.

**Table 6. Post-injection phase pressure-front monitoring.**

Target Formation	Monitoring Activity	Monitoring Location(s)	Frequency
<b>DIRECT PRESSURE-FRONT MONITORING</b>			
	Pressure and temperature		Continuous
<b>INDIRECT PRESSURE-FRONT MONITORING</b>			
All strata	Seismicity	AoR	Continuous





### ***Schedule for Submitting Post-Injection Monitoring Results [40 CFR 146.93(a)(2)(iv)]***

All post-injection site care monitoring data and monitoring results collected using the methods described above will be submitted to EPA in annual reports submitted within 90 days following the anniversary date on which injection ceases. The reports will contain information and data generated during the reporting period, i.e. well-based monitoring data, sample analysis, and the results from updated site models.

### **Non-Endangerment Demonstration Criteria**

Prior to authorization of site closure, CTV will submit a demonstration of non-endangerment of USDWs to the Director as per 40 CFR 143.93(b)(2) or (3).

CTV will provide a report to the Director that demonstrated USDW non-endangerment based on the evaluation of site monitoring data. The report will detail how the non-endangerment determination is based on site-specific conditions, supported with the computational model. All relevant monitoring data and interpretations will be provided.

### **Summary of Monitoring Data**

A summary of the site monitoring data, pursuant to the Testing and Monitoring Plan and this PISC and Site Closure Plan, including data collected during the injection and PISC phases of the project. Data submission will be in a format acceptable to the Director and will include:

1. A narrative that explains the monitoring activities,
2. Dates of all monitoring events,
3. Changes to the monitoring program over time,
4. An explanation of all monitoring information that has existed at the site,
5. Explanation of how the monitoring data from injection and PISC has varied from the baseline data during site characterization, and
6. Summary of any emergencies that occurred during the injection and post-injection phases of the project. Included will be a description of how any issues have been resolved and that there is no endangerment to the USDW.

## **Evaluation of the CO<sub>2</sub> Plume and the AoR**

Computational modeling results calibrated with monitoring data (e.g., pressure) will be used to support that the plume has stabilized and that the pressure change is negligible (less than 10 psi per year) and poses no risk for potential vertical migration. Computational modeling results calibrated with monitoring data from storage reservoir, USDW and above zone will be used to demonstrate:

1. the lack of CO<sub>2</sub> leakage over the project timeframe,
2. the accuracy of the model to predict and represent the storage reservoir, and
3. the computational model adequately defined the AoR.

## **Evaluation of Reservoir Pressure**

Monitoring data will be reviewed to ensure that the CO<sub>2</sub> plume has stabilized post-injection and that the reservoir pressure change is negligible (less than 10 psi per year). This demonstration will be supported by the computational model that has been calibrated with the most recent monitoring data. The plume is trapped by structure and pinch-out of the reservoir sands. Plume migration is minimal, as such pressure stabilization will be used for non-endangerment assessment.

## **Evaluation of Potential Conduits for Fluid Movement**

Wells that require corrective action will be reviewed and assessed prior to PISC and Site Closure, this includes monitoring wells, injection wells and other wells that penetrate within the AoR and the confining layer. Final demonstration will be made that natural and artificial conduits will not allow fluid migration from the storage reservoir.

## **Evaluation of Seismicity Monitoring**

Demonstration will be made that the plume has stabilized and the pressure change is negligible (less than 10 psi per year), minimizing the risk for induced seismicity after site closure. Final review will be made with the seismicity monitoring to demonstrate seal integrity and that there is no further endangerment of to the USDW.

## **Site Closure Plan**

CTV will conduct site closure activities to meet the requirements of 40 CFR 146.93(e), with notification to the permitting agencies at least 120 days prior to its intent to close the site. Upon approval of the permitting agencies, CTV will plug the injection and monitoring wells, restore the site and submit a site closure plan to the EPA.

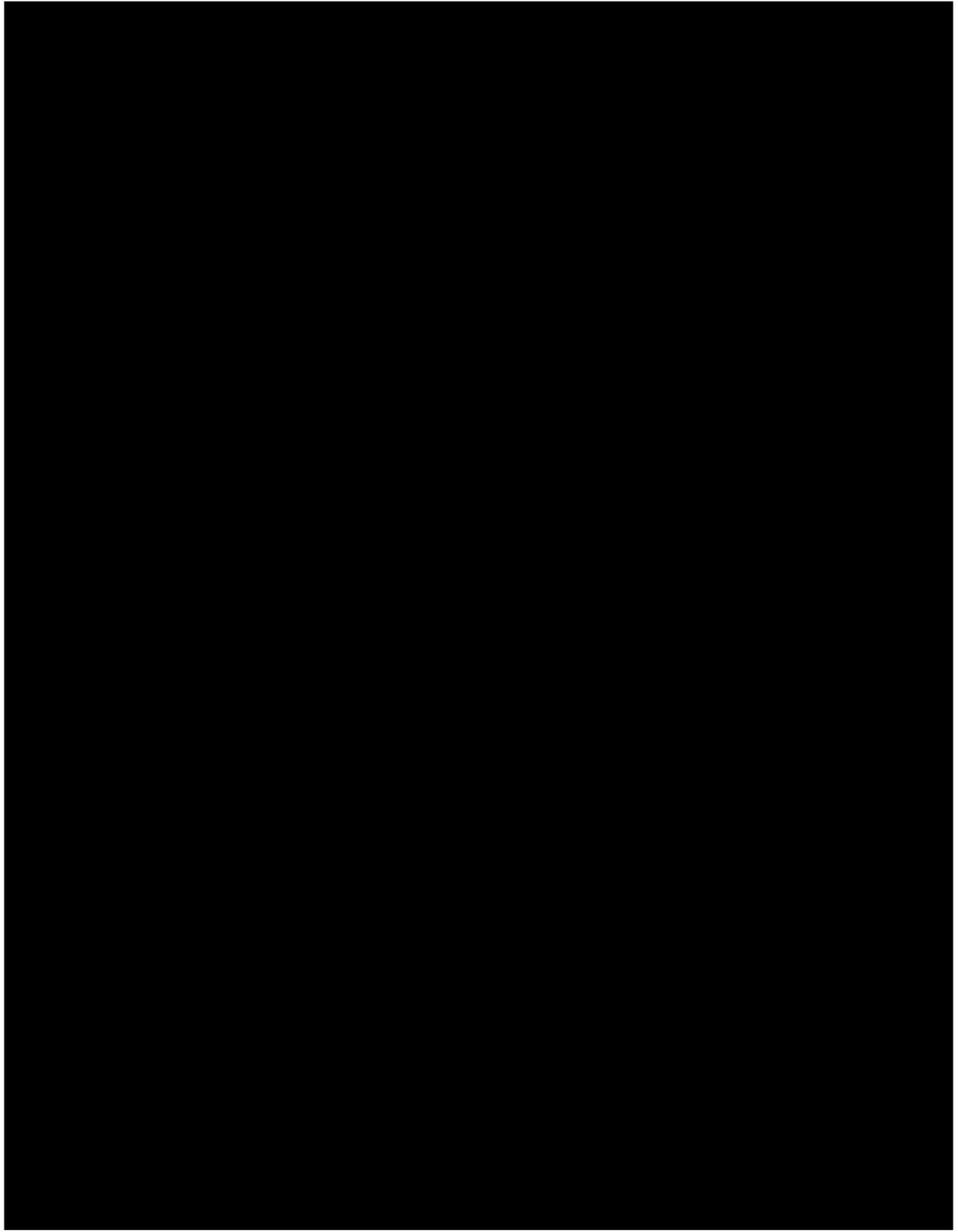
A site closure report will be prepared and submitted within 90 days following site closure supported by the following:

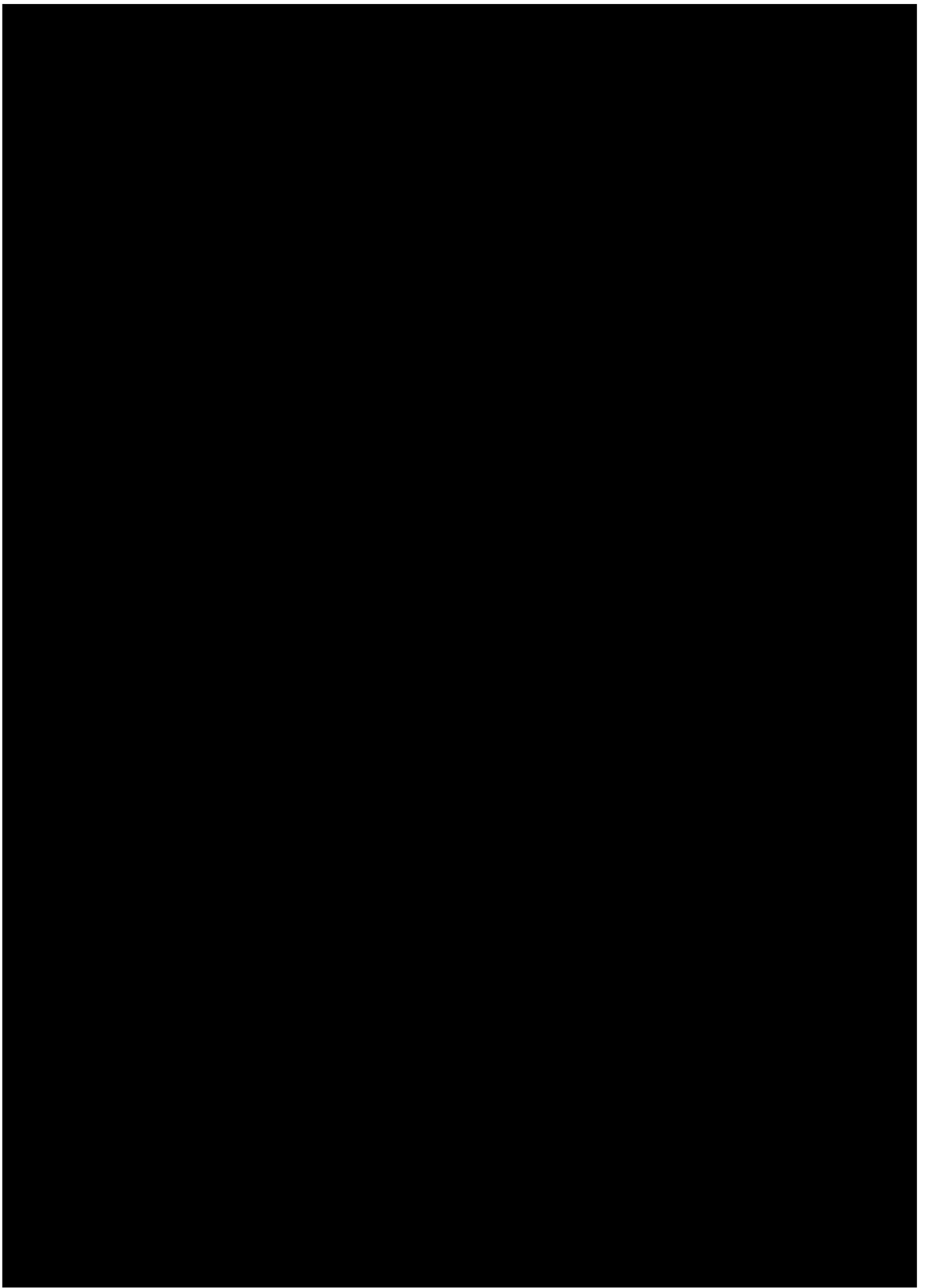
1. Verification of injector and monitoring well plugging,
2. Notifications to state and local authorities as per 40 CFR 146.93 (f)(2),
3. Composition and volume of the injected CO<sub>2</sub>, and
4. Post-injection monitoring records

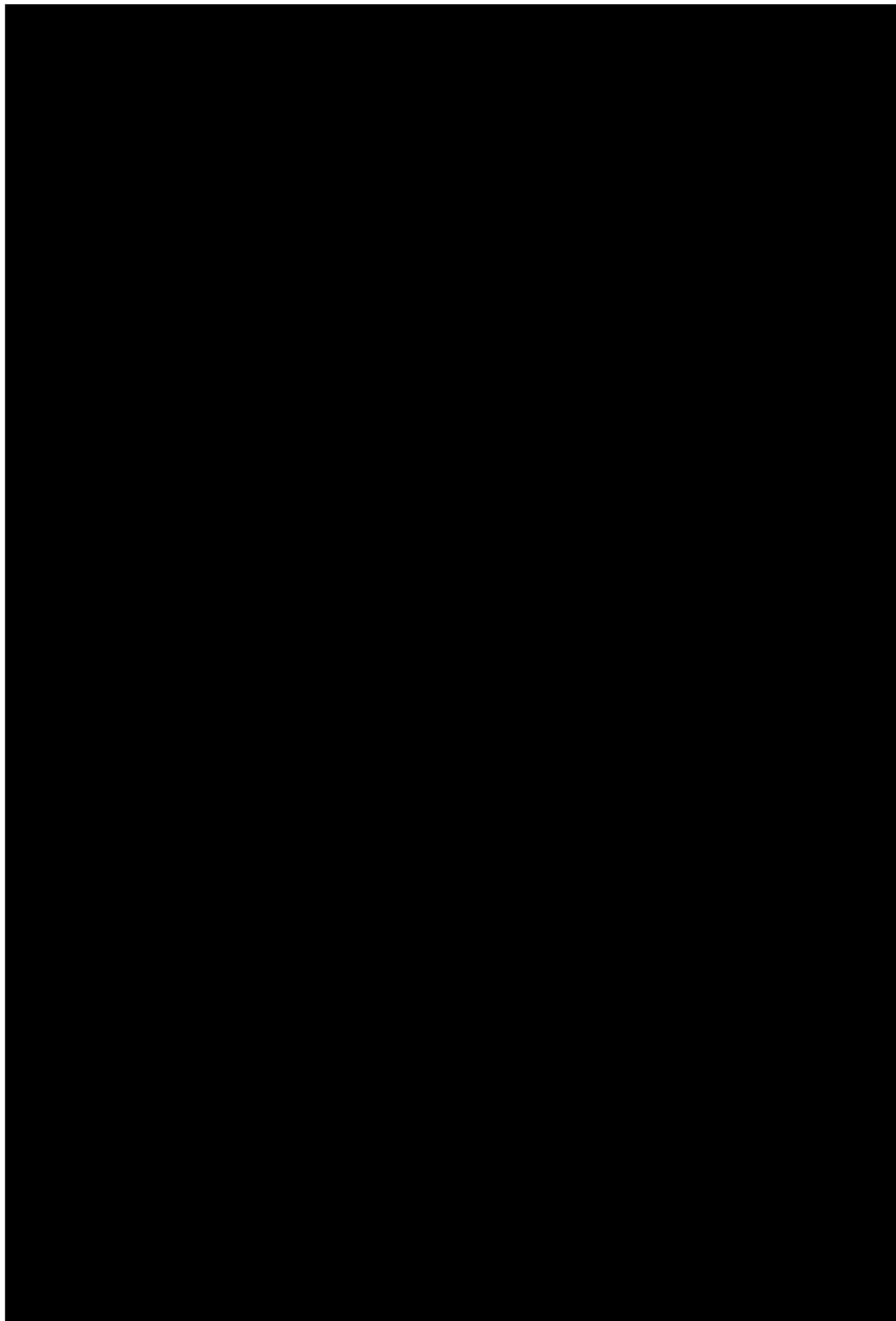
CTV will record a notation to the property's deed that will indicate:

1. The property was used for CO<sub>2</sub> sequestration, the period of injection and the volume of CO<sub>2</sub> injected,
2. The formation that the fluid was injected, and
3. The name of the local agency to which a plat of survey with injection well locations was submitted.

## **POST INJECTION SITE CARE AND SITE CLOSURE PLAN - FIGURES**







The first of these is the fact that the system is not a simple one. It is a complex system, and as such, it is not possible to understand it by looking at its parts in isolation. The system is a whole, and it is only by looking at the whole that we can understand it. This is the first principle of systems thinking: the whole is greater than the sum of its parts.

The second principle is that the system is dynamic. It is not a static system, but a system that changes over time. The system is a process, and it is only by looking at the process that we can understand it. This is the second principle of systems thinking: the system is a process.

The third principle is that the system is interconnected. The system is not a collection of independent parts, but a collection of parts that are interconnected. The system is a network, and it is only by looking at the network that we can understand it. This is the third principle of systems thinking: the system is a network.

The fourth principle is that the system is self-organizing. The system is not a system that is imposed from the outside, but a system that organizes itself from within. The system is a self-organizing system, and it is only by looking at the self-organizing process that we can understand it. This is the fourth principle of systems thinking: the system is a self-organizing system.

The fifth principle is that the system is resilient. The system is not a system that is fragile, but a system that is resilient. The system is a resilient system, and it is only by looking at the resilient process that we can understand it. This is the fifth principle of systems thinking: the system is a resilient system.

The sixth principle is that the system is adaptive. The system is not a system that is rigid, but a system that is adaptive. The system is an adaptive system, and it is only by looking at the adaptive process that we can understand it. This is the sixth principle of systems thinking: the system is an adaptive system.

The seventh principle is that the system is sustainable. The system is not a system that is unsustainable, but a system that is sustainable. The system is a sustainable system, and it is only by looking at the sustainable process that we can understand it. This is the seventh principle of systems thinking: the system is a sustainable system.

The eighth principle is that the system is equitable. The system is not a system that is inequitable, but a system that is equitable. The system is an equitable system, and it is only by looking at the equitable process that we can understand it. This is the eighth principle of systems thinking: the system is an equitable system.

The ninth principle is that the system is just. The system is not a system that is unjust, but a system that is just. The system is a just system, and it is only by looking at the just process that we can understand it. This is the ninth principle of systems thinking: the system is a just system.

The tenth principle is that the system is beautiful. The system is not a system that is ugly, but a system that is beautiful. The system is a beautiful system, and it is only by looking at the beautiful process that we can understand it. This is the tenth principle of systems thinking: the system is a beautiful system.